

7 SAFETY

To maintain the confidence that the aviation community and the flying public have in the NAS, the FAA is addressing system safety issues associated with modernization. Aviation system safety is the top priority of the FAA, and it will continue to be the top priority as the NAS is modernized and as capacity, efficiency, and flexibility increase.

First, system safety will be enhanced through incremental implementation of new systems while legacy systems continue operation. Second, NAS safety will be enhanced as new technology is introduced and system safety principles are applied in their design. Human performance considerations will be incorporated in the advanced automation technology. New and improved technology will provide pilots and controllers with better information for flight planning and operations and increased situational awareness, and enhanced decision support tools will increase efficiency.

Situational awareness is essential to safe flight. Modernization aims to enhance navigation/station-keeping, in-flight collision awareness/avoidance, terrain and obstacle awareness/avoidance, airspace boundary awareness, weather awareness, and onboard surveillance. Other aircraft and flight planning related applications will also be provided. Advancements in technology will support situational awareness without taking pilots out of the loop and without reducing the time for essential functions such as scanning the airspace.

Safety will be built in from the beginning by identifying where modernization initiatives will require major changes in safety risk management procedures and by applying system safety principles to their development. System safety principles use risk management techniques to systematically identify safety-related risks and provide mitigation to ensure that these risks are eliminated or controlled to an acceptable level. The system safety process includes hazard analysis, risk assessment, risk mitigation, and risk management. Objectives of system safety programs are to design a systematic approach to make sure that:

- Safety is designed into the system in a cost-effective manner

- Hazards are identified, tracked, evaluated, and eliminated, or the associated risk is reduced to an acceptable level
- Historical safety data and lessons learned are considered and used
- Minimum risk is sought in accepting and using new technology, materials, designs, or operational techniques
- Actions are taken to eliminate hazards or reduce risks to an acceptable level
- Changes in design, configuration, or requirements are accomplished in a manner that maintains an acceptable risk level
- Significant safety information is documented, stored, and used in applicable designs and specifications.

The order of priority for satisfying system safety requirements and resolving identified hazards will be to:

- 1) Design for minimum risk
- 2) Incorporate safety devices
- 3) Provide warning devices
- 4) Develop procedures and training.

The high safety levels of our current aviation system stem from effective risk management, which is based on the following complementary factors:

- Redundancy in certified air traffic control equipment
- Recognized air traffic control standards and procedures
- Thorough controller and aircrew training and certification
- Thorough maintenance technician training and certification
- Evolutionary improvements in aircraft design, crew training, operational procedures, and supporting technologies.

These complementary factors are the foundation of safety-related risk management and the public's high confidence in aviation safety.

It is important to assess any changes in the NAS from a system safety viewpoint—for example, how changes will affect interfaces, interactions, and redundancies that contribute to the aviation system’s inherent safety. Before use, each component of the new architecture will be thoroughly tested to ensure that safety is not degraded by new hardware, software, or procedures. This assessment is also required by FAA Order 8040.4.

7.1 NAS Capabilities

NAS modernization will enhance safety through more effective risk management in critical areas of the aviation system. Recently, the FAA’s focused safety agenda, “Safer Skies,” identified high-priority safety concerns. Additionally, the FAA administrator has established a risk management policy and has implemented safety risk management as a decisionmaking tool within the FAA. Modernization will strengthen safety risk management in several of these high-priority areas by reducing the potential for controlled flight into terrain and runway incursions, improving flow control of approach and landing operations, and providing better weather information. The following paragraphs describe specific architectural changes that can improve NAS safety.

7.1.1 Navigation, Landing, and Lighting

The navigation and landing portion of the NAS architecture provides system safety improvements by:

- Replacing existing ground-based nonprecision approaches (i.e., approaches dependent on horizontal guidance from ground-based navigation aids) with more precise Global Positioning System/Wide Area Augmentation System/Local Area Augmentation System (GPS/WAAS/LAAS) approach capabilities, which provide vertical descent guidance to all GPS approaches
- Combining GPS with cockpit electronic maps of terrain to enhance cockpit situational awareness.

Eventually, a GPS-based approach will be available at almost every location within the NAS,

supported by airport development and the formulation of instrument procedures.

A review of National Transportation Safety Board (NTSB) accident statistics for the United States concluded that approaches with vertical descent guidance (precision approaches) are several times less likely to experience an accident than approaches that lack vertical descent guidance (non-precision approaches). A related study by the Flight Safety Foundation came to the same conclusions for international air operations.¹

7.1.2 Surveillance

The entire inventory of terminal primary radar systems will become digital as the airport surveillance radar (ASR)-11 is completely fielded, and ASR-7 and ASR-8 equipment is decommissioned. Digital radars, for technological reasons, are more capable of detecting smaller aircraft at low altitudes, particularly in background clutter conditions. ASR-9 and ASR-11 digital radar systems also provide an improved weather detection and display capability. These improved capabilities can improve safety in terminal airspace.

The entire secondary surveillance radar (SSR) inventory will migrate to a selective interrogation capability. This capability will be modified to acquire position and velocity data from aircraft equipped with automatic dependent surveillance broadcast (ADS-B) via ground-initiated communications broadcast (GICB).

GPS information will improve target-tracking accuracy and enhance the functionality of various air traffic control decision support system (DSS) tools, such as conflict alert, conflict probe, trial planning, descent advisor (DA), Final Approach Spacing Tool (FAST), etc. Improved surveillance accuracy and tracking, linked with DSSs, will significantly aid controllers in separating aircraft from other aircraft, obstacles, and special use airspace (SUA).

Cockpit display of traffic information (CDTI), incorporating ADS-B information, will display nearby traffic, further enhancing cockpit situational awareness and safety.

1. Based on a review by FAA’s National Aviation Safety Data Analysis Center of the National Transportation Safety Board accident statistics covering 1983 through 1996 and a 1996 Flight Safety Foundation report covering worldwide commercial jet transport accidents, 1958–1995.

7.1.3 Communications

New digital communications systems, including data link, are expected to decrease verbal air traffic control (ATC) miscommunication of information such as headings, altitudes, or runway clearances. Flight information service (FIS) data link will provide other flight safety information such as current and forecast weather information, notification of navigational equipment status, airfield status, etc. Controller-to-pilot data communications allow controllers to communicate more effectively with aircraft in a congested voice radio environment.

Traffic information service (TIS) will support cockpit displays of other nearby aircraft and call attention to those that are on a converging or intersecting path. For time-critical applications, continuous and automatic information updates will be possible via data link services.

Safety can be improved in many areas by enhanced communications. For example, information about aircraft position is essential to situational awareness and collision avoidance. Aircraft flight object information and enhanced surveillance information will be necessary for flights in areas that do not have radar coverage.

Weather advisory information disseminated through automatic terminal information service (ATIS) and data link can give pilots more timely warnings of hazardous weather and other airport conditions. The next-generation air-ground communications system (NEXCOM) will improve voice communications and data link services, providing both on the same digital radios. NEXCOM will increase the number of usable radio frequencies, enabling better air traffic management.

7.1.4 Avionics

Increased navigational accuracy of GPS-based avionics and nearly universal availability of GPS signals are important improvements over today's navigation aids. GPS, WAAS, and LAAS avionics will provide approach course and vertical descent guidance to pilots for instrument approaches.

WAAS-augmented GPS will provide a navigational signal in space down to Category I (CAT I) minimums at suitably equipped airports. This capability alone is an important improvement over

all previous nonprecision instrument procedures such as very high frequency omnidirectional range (VOR), tactical air navigation (TACAN), automatic direction finder (ADF), nondirectional beacon (NDB), and localizer (LOC). These nonprecision approach methods currently depend upon the pilot to establish a suitable rate of descent to arrive at the minimum descent altitude at or before the missed-approach point.

As a practical matter—and putting aside the traditional association of precision approaches with decision heights of 200 feet or less—all GPS procedures will be capable of being used to fly precision approaches (i.e., with both course and vertical guidance). Precision approaches are an improvement over nonprecision approaches in maintaining obstacle/terrain clearance. This satellite-based navigation capability could decrease risks associated with controlled flight into terrain—one of the most common types of fatal accidents in aviation.

WAAS can also improve the accuracy of ground proximity warning systems and, in conjunction with digital terrain data bases, could further reduce the risk associated with controlled flight into terrain.

GPS (augmented by WAAS to meet system safety, availability, and reliability requirements) is expected to be the basis for improved situational awareness through the use of ADS-B and CDTI. Satellite systems also improve navigation on the airport surface during reduced visibility conditions via a moving map display that helps flight crews maintain orientation, even with reduced visual references.

Data link services can aid pilots and controllers by providing quicker and more accurate data exchange. Weather data exchange will give pilots a greater understanding of the winds and weather in a planned flight path. Digital radios will enable clearer voice communication between pilots and controllers and are less susceptible to interference.

Modernization attempts to increase situational awareness and support future operations through human-centered decision support technologies for pilots, controllers, and planners.

7.1.5 Information Services for Collaboration and Information Sharing

Information sharing facilitates controller-pilot collaboration. Local and NAS-level common information services will be used to provide information to pilots and traffic flow planners. Better information can allow selection of the most effective route to destination and alternate airfield and can provide warning of hazardous conditions. Additionally, providing real-time weather information directly to aircrews is essential to identifying hazardous weather conditions. Flight safety can be enhanced by automatic, simultaneous broadcast to the flight deck and service providers of hazardous weather alerts for windshear, microbursts, and gust fronts, as well as icing, turbulence, and thunderstorm information. For the foreseeable future, voice transmission will also continue.

More timely NAS status information, such as runway closings, airport construction, or temporary obstructions, can help aircrews avoid hazards and be better prepared if navigation or airfield facilities become inoperative.

7.1.6 Traffic Flow Management

Traffic flow management (TFM) decision support systems (DSS) work to mitigate demand-capacity imbalances through early prediction and collaborative resolution. These systems will allow better use of system capacity without unsafely overloading either controllers or pilots.

7.1.7 En Route

Automated tools are expected to further improve collision avoidance and reduce operational errors and deviations. New DSSs, such as conflict probe, can monitor aircraft position, predict potential conflicts, and suggest resolutions further in advance than can current alerts. Traffic Management Advisor (TMA) will calculate a more efficient and orderly sequence of arriving aircraft as they approach the terminal area.

Other tools can send ground proximity alerts to help mitigate controlled flight into terrain risk and provide alerts to warn of potential flight into restricted airspace. The planned use of automatic dependent surveillance (ADS) in nonradar areas will extend the benefits associated with radar air

traffic services to increasing portions of en route airspace.

7.1.8 Oceanic

The use of satellite communications (SATCOM) and high frequency data link (HFDL) by oceanic service providers and users will provide real-time communications and electronic message routing. This capability will constitute the basis for ADS in oceanic airspace and give controllers more accurate positional data on oceanic flights. This improvement should allow a reduction in separation distances and still maintain or improve safety over the current levels. New oceanic conflict probe and conflict alert decision support tools can be used to help service providers detect and resolve potential conflicts and help prevent controlled aircraft from entering restricted airspace.

7.1.9 Terminal

Controllers will use improved automated conflict detection tools and enhanced ATC displays to separate aircraft from other aircraft (those either on the ground or in the air) and from restricted airspace, terrain, and hazardous weather. Controllers will use integrated weather information, including windshear and microburst alerts, to assist pilots in avoiding hazardous weather and to improve the flow of traffic in terminal airspace. Tools, such as Controller Automation Spacing Aid (CASA) and Converging Runway Display Aid (CRDA), allow controllers to refine the arrival flow of converging aircraft to the primary airport, increasing airport capacity while maintaining safe separation standards. Advanced tactical flow control tools, such as active FAST and DA, promote a steadier flow of aircraft into the terminal airspace.

7.1.10 Tower/Airport Surface

New airport surface detection equipment (ASDE-3) combined with the airport movement area safety system (AMASS) will alert controllers to potential conflicts between arriving aircraft and surface traffic and between aircraft and vehicles at 34 high-use airports. Additional radar and conflict-alerting systems are being planned for other airports. Satellite-based navigation systems, including those augmented by LAAS, improve situational awareness for surface operations. Integrat-

ing ADS data with radar data and enhanced ATC displays for airport surface surveillance will further improve surface conflict detection.

7.1.11 Flight Planning

The Operational and Supportability Implementation System (OASIS) at the automated flight service stations (AFSSs) collects information from multiple weather sensors, FAA systems, and other sources. OASIS provides improved weather graphics, route-oriented briefings, notices to airmen (NOTAMs), and SUA notifications and warnings. This information is essential for flight planning and can be very important during a flight. Data link improves in-flight access to flight service station (FSS) specialists.

7.1.12 Weather

Improvements in detecting and forecasting weather can help aircraft avoid hazardous weather situations. The airport surveillance radar-weather system processor (ASR-WSP) expands NAS windshear detection and alert capability. The integrated terminal weather system (ITWS) integrates data from multiple sensors and sources to produce windshear, microburst, and gust front alphanumeric and graphic forecast products to provide improved automated weather information and predictions. Broadcasting ITWS information via the terminal weather information for pilots (TWIP) system to aircraft in or approaching terminal airspace also gives pilots a better opportunity to avoid thunderstorms, hail, icing, and turbulence. ITWS supports proactive rerouting to avoid windshear or severe weather.

In a similar manner, the weather and radar processor (WARP) will provide improved weather data for en route service providers. In particular, WARP provides the weather data from the Doppler next-generation weather radar (NEXRAD) to en route controller displays.

Weather information will be made available, via tailored broadcast or upon request, from a common network available to all NAS users. The FAA will make NAS status and existing weather data available to private data link service

providers for the development of FIS products. Commercial providers may make basic FIS products available, at no cost to the government or the user, and may make value-added products available for a fee.

Current and predicted hazardous weather data will be integrated and presented on controller displays. Weather data down-linked from aircraft reporting in-flight conditions will improve weather forecasts. Integrated weather products will be up-linked to the cockpit, initially by FIS to assist pilots in avoiding hazardous weather. An improved and shared view of weather information among aircrews, controllers, dispatchers, and meteorologists enhances weather communications by increasing understanding of weather and permitting collaborative replanning of flights.

7.1.13 NAS Infrastructure Management System

The NAS maintenance workforce will have critical NAS component status information available for remote diagnosis of system problems. A fully fielded maintenance management system will allow technicians to provide more timely and effective maintenance of the NAS infrastructure. Greater availability, quicker restoration, and improved reliability of NAS infrastructure components will enhance the NAS.

7.2 Safety Metrics

Several data sources are available to assess NAS safety. The NAS safety metrics provide baseline information for the NAS as it is modernized. Tables 7-1 and 7-2 show safety trends for the years between 1990 and 1997 for a variety of safety indicators and some of the metrics presently used.

Safety measurement can be based on the record of lessons learned from accidents and incidents. Over the past 30 years, accident rates have decreased for large air carriers and commuter operations.² This is the result of both technological and operational changes within the NAS. The accident rate, however, is an after-the-fact measure, which uses past data as a yardstick, which can be

2. Based on National Transportation Safety Board accident statistics for U.S. commercial air carrier accidents, received from the NTSB Public Inquiries Section. This also applies to the worldwide commercial jet fleet, based on statistics released by the Airplane Safety Engineering Division of the Boeing Commercial Airplane Group.

Table 7-1. Accident Trends

Safety Indicator	Description of Aviation Accident Rates	Trend (1990–1997)
Large Air Carrier Accident Rates	This indicator compares the number of accidents involving all large air carriers (i.e., operating under Federal Aviation Regulation (FAR) Parts 121 or 127) to the number of flight hours and departures for these carriers.	Steady for 1990 through 1994 at a low rate; an increase for 1995 through 1997.
Commuter Air Carrier Accident Rates	Compares the number of accidents involving all commuter air carriers (i.e., scheduled carriers operating under FAR Part 135) to the number of flight hours and departures for these carriers.	Up from 1990 to 1991; steady from 1991 through 1992; improving from 1992 through 1994 at a low rate; an increase from 1995 through 1997.
Air Taxi Accident Rates	Compares the number of accidents involving all air taxis (i.e., nonscheduled air carrier operations under FAR Part 135) to the number of air taxi flight hours.	Steady.
General Aviation Accident Rates	Compares the number of accidents involving all general aviation aircraft to the number of general aviation flight hours.	Steady.
Mid-Air Collision Accident Rate	Compares the number of mid-air collision accidents involving all operator types to the number of flight hours for all operators (i.e., large air carrier flight hours + commuter flight hours + air taxi flight hours + general aviation flight hours).	About the same rate from 1990 through 1996, with a dip in the middle years; improvement in 1997.

Table 7-2. Incident Trends

Safety Indicator	Description of Aviation Incident Rates	Trend (1990–1997)
Pilot Deviation Rates	Compares the total number of pilot deviations to total system flight hours.	Down from 1990 through 1995; up in 1996 and 1997.
Near Mid-Air Collision Reports (NMACs)	Presents the total number of system reported NMACs.	Downward trend overall; slight rise in 1997.
Air Carrier Near Mid-Air Collision (NMAC) Rates	Compares the number of NMACs involving all air carriers (i.e., those operating under FAR Parts 121, 127, 129, and 135) to the number of air carrier flight hours.	Downward trend overall; slight rise in 1997.
Operational Error Rates	Compares the total number of operational errors to the total number of facility activities.	Steady.
Runway Incursion Rates	Compares the number of runway incursions that occur at airports to the number of operations at the airports.	Down from 1990 through 1993; up from 1994 through 1997.
Vehicle/Pedestrian Deviation Reports (VPDs)	The number of VPDs. A VPD is an entry to or movement on an airport movement area by a vehicle (including aircraft operated by a nonpilot) or pedestrian that has not been authorized by air traffic control.	Downward trend with fluctuations.

used to predict future behavior and assess risks associated with NAS changes.

System safety risk assessment provides a more proactive approach by identifying safety-related risks early and by applying risk elimination and risk control. This enhancement improves safety.

The NAS is monitored from a system safety approach that acquires accident and incident data. Examples of incidents include operational errors, near mid-air collisions, and pilot deviations. Incident data provide information about events that can lead to potential accidents. Additional metrics may be used over time.

7.3 Summary

Safety is improved through more effective mitigation of risks or elimination of underlying hazards. Extremely complex and effective mitigation strategies support the aviation system's inherent high

safety level. The development of the aviation system's mitigation strategies has been incremental and evolutionary as improvements have been made in aircraft design, crew training, operational procedures, and supporting technologies. Potential hazards have been eliminated through design, safety devices, or procedures. Redundancy has been successfully used as a mitigation strategy to reduce the probability that failure of a single element will lead to an accident. This safety risk assessment process will continue as the NAS is modernized to ensure that existing risk is minimized and new hazards are not introduced.

NAS modernization has the *potential* to reduce the number of accidents. Accident rates will not decrease unless the capabilities described in the NAS architecture are implemented and a high percentage of aircraft are equipped with new avionics. Implementation, of course, is dependent on

funding and the allocation of scarce resources. Acquisition and installation of new avionics is controlled by numerous users. Furthermore, even when implemented, the architecture's capabilities are not omnipresent; some are available only in selected airspace or at larger airports. A study³ of

particular reports of accidents involving turbulence, hazardous weather in the terminal area, airport surface operations, collisions between aircraft, and controlled flight into terrain indicates that accidents attributed to these factors can be reduced by NAS modernization.

-
3. *NAS Architecture and Safety*, a preliminary analysis performed by the FAA Office of System Development, January 1998, Wash., D.C.

